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A PROVENANCE TEST OF YELLOW BIRCH IN NEW BRUNSWICK

by

D.P. Fowler and Y.S. Park

Canadian Forestry Service - Maritimes
Fredericton, New Brunswick

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ABSTRACT

In the spring of 1968 a range-wide provenance trial of yellow birch, *Betula alleghaniensis* Britt., was established in southern New Brunswick in cooperation with the U.S.D.A. Forest Service. After 16 years, genetic variation among provenances is large in respect to survival, growth, stem quality and susceptibility due to some damaging agents. Correlation of these factors with geo-climatic variables is too weak to be useful in identifying areas of better provenance. Trees of provenances from south of latitude 45° N or from the northern and western limits of the species range do not perform well in New Brunswick. Age to age correlations are strong suggesting that better provenances can be identified at age 10 years.

Unless economical methods of planting and tending can be developed, the production of genetically improved yellow birch, although possible, does not appear to be a viable alternative to natural regeneration methods. An inexpensive method for the genetic improvement of yellow birch seeds to service a modest reforestation program is presented.

RÉSUMÉ

On procède depuis le printemps de 1968, en collaboration avec le Service forestier du Ministère fédéral américain d'Agriculture, à un test de provenance à la grandeur de l'aire de distribution du bouleau jaune, *Betula alleghaniensis* Britt., dans le sud du Nouveau-Brunswick. Après 16 ans, la variation génétique entre les provenances est considérable pour ce qui est du taux de survie et de croissance, de la qualité des tiges et de la sensibilité à certains agents nuisibles. La corrélation entre ces facteurs et les variables géo-climatique est trop faible pour nous permettre d'identifier les régions à meilleures provenances. Les arbres de provenances des régions au sud du 45° de latitude Nord ou des limites nord et ouest de l'aire de distribution de l'espèce n'ont pas un bon rendement au Nouveau-Brunswick. Les coefficients de corrélation d'âge à âge semblent indiquer que les meilleures provenances peuvent être identifiées à l'âge de 10 ans.

À moins que l'on ne parvienne à mettre au point des méthodes économiques de plantation et d'entretien, la production de bouleau jaune de composition génétique améliorée, même si elle est possible, ne semble pas constituer une solution de rechange viable aux méthodes de régénération naturelle. Une méthode peu coûteuse d'amélioration génétique des semences de bouleau jaune, pour un programme modéré de reboisement, est présentée.

INTRODUCTION

Yellow birch, *Betula alleghaniensis* Britt., is one of the largest and most important hardwoods in northeastern North America. Logs of high quality are in demand for dimensional stock and veneer and wood is also in demand for kraft pulp and paper. Although an important forest species, yellow birch is not an important component of any reforestation program.

The range of yellow birch extends from Newfoundland to western Minnesota and south along the Appalachian Mountains to northern Georgia (Figure 1). Clausen (1973a) provides a detailed review of the taxonomy and evolution of the species. Although hybrids of yellow birch and *B. pumila* L. are common in southern parts of the Lake States (Dancik and Barnes 1972) and hybrids of yellow birch and *B. papyrifera* Marsh. occasionally occur over a large part of the species range (Clausen 1973a), natural hybridization does not appear to be an important contributor to variation in this species (Clausen 1973a).

Much of the information on genetic variation in yellow birch is derived from a series of provenance trials organized by the U.S.D.A., Forest Service, Rhinelander, Wisconsin (Clausen 1973a). Results from the nursery phase of this study indicated minor differences in second year survival. Seedlings of all provenances showed evidence of winter injury although those from northern and eastern provenances were generally less damaged. Differences among provenances in respect to growth, although highly significant, appeared to be random (Clausen

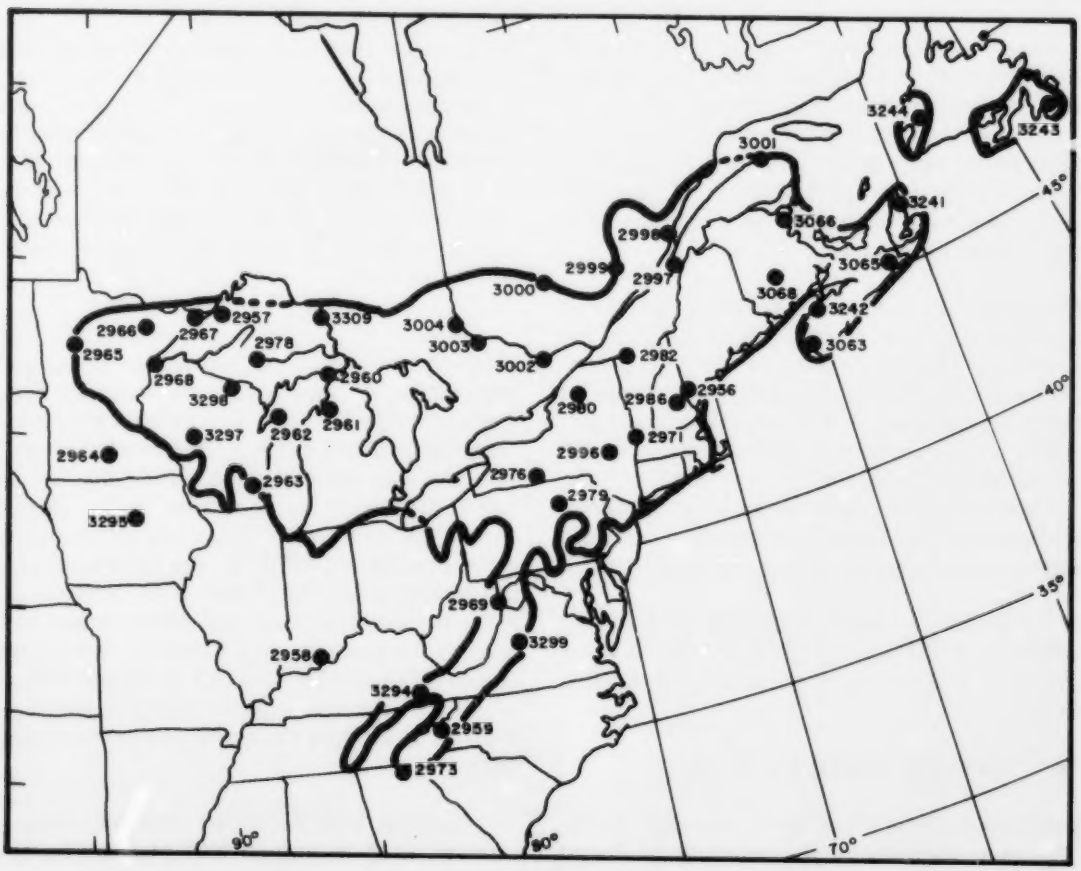

Figure 1. Natural range of yellow birch and location of 45 provenances tested at McDonald Corner, N.B. Adapted from Clausen (1968).

and Garrett 1969). The lack of a well defined pattern of variation for seedling height was also reported in a study of 46 Quebec provenances at 2 years of age (Corriveau 1971 *in* Clausen 1973a). Within-provenance variation for seedling height at ages 2, 3, and 4 years and diameter at 4 years, is often greater than differences among widely separated provenances (Clausen 1973b).

Variation among provenances in respect to growth initiation and especially growth cessation is essentially clinal (Clausen 1968, Clausen and Garrett 1969, Sharik 1970). In general, trees from high latitudes and high elevations tend to flush later and stop growth earlier than those from lower latitudes and lower elevations. For both growth initiation and growth cessation, there are a number of provenances which do not fit the general variation pattern. Variation in growth initiation and cessation is less important within provenances than between provenances (Clausen 1973a).

Between 1966 and 1968, eleven field trials of seedlings from 30 to 55 provenances were established in the United States and Canada. Survival in six of the trials was too low for valid comparisons. Clausen (1975) reported on survival and growth of the other five trials at age 5 years from planting. These are located in Wisconsin, Michigan (2), New York, and New Brunswick.

At five years of age, provenance appeared to be an important source of variation for survival in the three northern trials with trees of northern provenance exhibiting better survival than those of southern provenance. In the two more southern trials this pattern was not evident. Variation in 5-year height did not exhibit any well defined pattern and the interaction between provenance and test location was large. Few provenances were consistently good over all location (Clausen 1975).

In this paper we describe survival, growth, and susceptibility to damaging agents to age 16 years for the provenance trial established in New Brunswick.

MATERIALS AND METHODS

Materials for this study were provided by Dr. K.E. Clausen, formerly of the Institute of Forest Genetics (IFG), United States Forest Service, Rhinelander, Wisconsin and are part of IFG cooperative test G. 242. For more information concerning the seed and seedling aspects of this test, the reader is referred to Clausen (1973a).

Seeds for this study were collected in 1963 and 1964 by cooperators in the United States and Canada (Table 1, Figure 1). The seeds were germinated in flats in May 1965 and transplanted into four complete blocks at the Hugo Sauer Nursery at Rhinelander where they were raised as 3-0 stock. On April 24, 1968, 40 seedlings from each of 45 provenances were shipped, air freight, and arrived in Fredericton on April 26. The seedlings arrived in good condition and were inspected (Can. Dept. Agric., Plant Protection) and placed in cold storage (2° C) until just prior to planting on May 9, 10, and 11. All seedlings were watered by hand on May 11 and on May 19 they were again watered using a portable irrigation system.

The test site is at McDonald Corner, N.B. 75km SSE of Fredericton on former agricultural land. The test site was plowed in the fall of 1967 and disked in the spring of 1968. The seedlings were planted at 2.4 x 2.4m (8 x 8 ft.) in a randomized block design with 4-tree square plots, replicated 10 times (Appendices I and II). A double row of 2-2 white birch of local origin was planted around the test on May 28. Replicates 1 and 2 are situated on a former hay field which is stony and poorly drained. Replicates 3 to 10 are on a former strawberry field which is moderately stony and fresh.

Several of the provenances had one to three seedlings missing . All misses were assigned to Replication 9. The missing seedlings, as well as a few seedlings that died shortly after planting were replaced with 4-0 stock from Rhinelander in 1969. The test was weeded once during the summer of 1968. Damage by meadow voles (*Microtus pennsylvanicus* Ord.), which was fairly severe during the winter of 1969-70, was subsequently controlled with poison grain bate. In the summer of 1970 a 1 x 1m sheet of black polyethylene was secured around the base of each seedling to help control weeds. In December 1980, all surviving trees, many of which had developed multiple stems, were thinned to a single stem and pruned to a height of 2.5m (Figure 2).

Survival was recorded annually from 1969 through 1973. In August 1971 (4 years from planting), the following observations or measurements were recorded: total height, stem form (single vs. 2 or more), vole damage, and insect (leaf miner,

Table 1. Origin and geo-climatic characteristics of 45 yellow birch provenances planted at McDonald Corner, N.B. (adapted from Clausen 1968)

Provenance No.	State or Province	Lat. (°N)	Long. (°W)	Elevation (m)	Growing season (days)	Parent trees (No.)
3243	Newfoundland	47.2	53.4	15	110	11
3244	"	48.6	58.2	120	110	10
3241	Nova Scotia	46.6	60.5	30	120	10
3065	"	45.4	61.8	105	102	18
3242	"	44.8	65.2	200	130	10
3063	"	44.1	65.8	105	140	10
3068	New Brunswick	46.0	66.4	90	126	1
3066	"	47.4	65.2	90	130	10
3001	Quebec	49.2	65.1	90	135	8
2998	"	48.2	70.2	305	107	15
2997	"	47.0	70.3	120	120	12
2999	"	47.4	72.6	305	107	15
3000	"	47.5	75.0	460	90	15
3002	Ontario	45.1	76.9	305	115	10
3003	"	46.1	79.0	305	115	10
3004	"	46.7	79.6	305	115	10
3309	"	47.5	84.8	305	110	10
2956	Maine	43.7	70.9	305	130	14
2986	New Hampshire	43.5	71.4	395	130	13
2982	Vermont	44.7	72.6	380	115	13
2971	Massachusetts	42.7	73.2	490	150	15
2980	New York	44.2	74.9	495	111	12
2996	"	42.5	74.2	640	135	8
2976	"	42.3	77.3	395	145	10
2979	Pennsylvania	41.3	76.3	700	150	10
2969	West Virginia	39.0	79.7	670	145	10
3299	Virginia	37.8	79.1	915	175	11
2959	North Carolina	35.7	82.3	1570	135	10
2973	Georgia	34.8	83.8	1430	185	10
3294	Kentucky	36.9	82.9	1100	180	10
2958	Indiana	38.3	86.5	215	165	7
3295	Iowa	42.4	93.1	320	150	10
2957	Michigan	47.9	89.1	230	120	10
2961	"	45.0	85.0	305	110	10
2960	"	45.9	84.8	190	140	10
2978	"	46.7	87.9	510	110	11
2968	Wisconsin	46.5	92.1	350	140	15
3298	"	45.7	89.0	520	110	10
3297	"	44.5	90.4	335	130	10
2962	"	44.9	87.2	180	145	10
2963	"	43.1	88.4	275	165	15
2964	Minnesota	44.2	94.1	245	150	12
2965	"	47.2	95.2	450	100	10
2966	"	47.6	92.5	520	110	10
2967	"	47.8	90.2	425	130	10

Bucculatrix canadensisella Chambers) damage. In November 1977 (10 years from planting), the following measurements or observations were recorded: survival, total height, number of stems, presence of catkins, and dead tops. In November 1983 (16 years from planting) the following measurements or observations were recorded: survival, total height, diameter breast height (DBH), single stem height, butt damage (caused by pruning in 1980), and presence of catkins.

Analyses of variance were performed based on 4-tree plot means. Once significant differences among provenances were identified, mean separation by cluster analysis (Scott and Knott 1974; Gates and Bilbro 1978) was performed. Correlation analysis was carried out using geo-climatic variables of the provenances and all the measured or observed characters.

RESULTS

Serious grass competition in replicates 1 and 2, accompanied by damage by meadow voles in the second winter, resulted in a survival rate which was too low for assessment. Consequently data from these two replications were dropped from the analysis.

Analyses of variance indicated that there were significant differences among provenance means for 12 of the 16 characters examined (Table 2). Correlation coefficients among the geo-climatic and observed characters are presented in Table 3.

Survival

Survival of provenances two years after planting ranged from 59 to 100% (mean 87%) (Table 4). At 10 and 16 years, survival ranged from 11 to 94%

Figure 2. Test of yellow birch from 45 provenances planted at McDonald Corner, N.B. in 1968 and thinned and pruned in 1980. Prior to (left) and after (right) thinning and pruning (Photograph by J.C. Lees).

Table 2. Analyses of variance for survival, growth, stem quality, damaging agents, and flowering characteristics of yellow birch from 45 provenances growing at McDonald Corner, N.B.

Characters	Mean squares[1] for Provenances	Error
Height at age 4 (HT4)	2611.29 **	1539.02
Height at age 10 (HT10)	1.90 **	0.69
Height at age 16 (HT16)	63.75 **	38.56
Single stem height at age 16 (SSH)	48.84 ns	52.90
DBH at age 16 (DBH)	321.55 **	187.01
Survival at age 4 (SUR4)	578.85 *	356.47
Survival at age 10 (SUR10)	1567.84 **	569.04
Survival at age 16 (SUR16)	1709.84 **	973.07
No. of single stem trees at age 4 (STEM4)	1.05 ns	1.27
Number of stems at age 10 (STEM10)	1.34 **	0.72
Vole damage by age 4 (VOLE)	0.92 ns	0.96
Leaf miner damage at age 4 (LEAF)	333.64 **	128.11
Trees with dead top at age 10 (DT)	0.02 ns	0.02
Butt damage at age 16 (BUTT)	0.54 **	0.26
Presence of catkins at age 10 (CAT10)	0.10 **	0.05
Presence of catkins at age 16 (CAT16)	0.26 **	0.11

[1]Degrees of freedom for provenances are 44 for all characters. Error degrees of freedom are 315, except for growth, butt damage, and presence of catkins at age 16 which are 283. **, *, and ns indicate significance level at 0.01, 0.05 and non-significanace, respectively.

(mean 77%) and 8 to 88% (mean 64%), respectively. Differences among provenances were highly significant at all ages and at age 16 grouped into two discrete clusters. Survival at ages 4 and 10 years was significantly correlated with survival at age 16 (r = 0.58 and 0.87, respectively).

Survival at all ages was correlated positively with latitude and negatively correlated with length of growing season at the place of origin. There were, however, some notable exceptions in that trees of the most southern, high elevation provenances, Georgia (2973) and North Carolina (2959) survived well. The other southern, high elevation, provenance from Kentucky (3294) had low survival as did all other provenances from south of latitude 43°N. Provenances close to the limit of the species range in the north, *i.e.*, Quebec (2999 and 3001), Newfoundland (3243) and New Brunswick (3066) as well as all the "outlier" provenances to the southwest of the species range, *i.e.*, Minnesota (2964), Iowa (3295) and Indiana (2958), also had low survival. With few exceptions, *i.e.*, Nova Scotia (3242), Wisconsin (3298), Ontario (3002), Vermont (2982), and Minnesota (2967), provenances from north of latitude 44°N and from well within the species range have above average survival and fall in the top discrete cluster.

Growth

Differences among provenances in height at all ages and DBH at age 16 were highly significant. Height at age 4 ranged from 127 to 239cm (mean 195cm) (Table 5), however, no discrete clusters could be identified at the 5% level. At 10 and 16 years, height ranged from 2.2 to 5.3m (mean 4.8m) and from 6.5 to 7.9m (mean 7.3m), respectively, with three and two clusters, respectively. DBH at age 16 ranged from 7.1 to 9.9cm (mean 8.7cm) and could be separated into two clusters.

Height at 4 years was correlated with height at 10 years (r = 0.46) and height and diameter at 16 years (r = 0.35 and 0.41, respectively). Height at 10 years was correlated with height and diameter at 16 years (r = 0.58 and 0.47, respectively). Height at 10 and 16 years and diameter at age 16 years were positively correlated with survival at 10 and 16 years.

The correlations of growth variables and geoclimatic variables of the provenances is not clear. At 4 years, height was not correlated with any of the

Table 3. Correlation coefficients for geo-climatic, survival, growth, stem quality, damaging agents and flowering of yellow birch from 45 provenances growing at McDonald Corner, N.B.

Variables[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. LAT	1.0																			
2. LONG	-0.0	1.0																		
3. ELEV	-0.74	0.33	1.0																	
4. GS	-0.78	0.0	0.44	1.0																
5. HT4	0.0	0.0	-0.0	-0.0	1.0															
6. HT10	0.43	-0.0	-0.0	-0.46	0.46	1.0														
7. HT16	0.0	-0.31	-0.0	-0.36	0.35	0.58	1.0													
8. SSH	0.0	-0.0	-0.0	-0.0	-0.0	0.0	0.64	1.0												
9. DBH	0.40	-0.30	-0.45	-0.38	0.41	0.47	0.73	0.33	1.0											
10. SUR4	0.34	-0.0	-0.0	-0.38	0.56	0.54	0.0	-0.0	0.0	1.0										
11. SUR10	0.46	-0.0	-0.0	-0.48	0.44	0.80	0.42	0.0	0.30	0.74	1.0									
12. SUR16	0.35	0.0	0.0	-0.44	0.49	0.77	0.42	0.0	0.30	0.58	0.87	1.0								
13. STEM4	0.0	-0.0	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0							
14. STEM10	-0.0	-0.0	0.0	0.0	0.0	0.52	0.0	-0.0	-0.0	0.0	0.40	0.41	0.32	1.0						
15. VOLE	-0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	0.0	-0.0	0.0	0.0	0.0	0.0	0.0	1.0					
16. LEAF	0.64	-0.0	-0.52	-0.58	0.35	0.0	0.0	0.0	0.0	0.29	0.0	0.0	0.0	-0.0	-0.0	1.0				
17. DT	-0.0	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	0.0	0.0	-0.0	0.0	0.0	-0.0	0.0	1.0			
18. BUTT	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	0.0	0.0	0.0	0.0	0.34	0.0	-0.0	0.0	1.0		
19. CAT10	0.0	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	0.0	0.32	-0.0	1.0	
20. CAT16	-0.37	-0.0	0.0	0.35	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	0.0	-0.0	0.37	0.0	-0.45	0.0	0.32	0.0	1.0

[1]LAT, LONG, ELEV and GS are latitude, longitude, elevation and growing season, respectively. See Table 2 for abbreviations of the remaining variables. Non-significant correlations at 0.05 level are replaced by 0.0.

Table 4. Mean percent survival of yellow birch from 45 provenances planted at McDonald Corner, N.B.

Provenance	Survival at ages		
	4	10	16
2956	96.9	87.5 C[1]	56.3 A[1]
2957	94.4	78.8 C	66.9 B
2958	63.2	11.7 A	7.5 A
2959	97.5	87.7 C	84.6 B
2960	88.1	81.9 C	74.2 B
2961	83.1	74.4 C	71.9 B
2962	83.1	80.6 C	75.6 B
2963	100.0	90.6 C	75.0 B
2964	85.0	72.5 C	54.4 B
2965	90.0	90.0 C	71.3 B
2966	85.6	85.6 C	81.0 B
2967	96.9	78.1 C	62.5 A
2968	94.4	88.1 C	81.9 B
2969	91.3	60.0 B	46.3 A
2971	82.5	72.1 C	61.3 A
2973	86.3	81.3 C	76.9 B
2976	85.0	75.6 C	52.5 A
2978	86.9	83.1 C	80.6 B
2979	90.6	63.5 B	42.7 A
2980	96.9	84.4 C	65.6 B
2982	86.0	75.6 C	62.5 A
2986	91.9	88.8 C	82.5 B
2996	85.0	57.5 B	60.0 A
2997	90.6	75.0 C	65.6 B
2998	100.0	90.6 C	75.0 B
2999	86.3	80.6 C	61.3 A
3000	91.3	88.8 C	74.2 B
3001	79.4	67.5 B	45.6 A
3002	96.9	87.5 C	62.5 A
3003	81.3	81.3 C	65.6 B
3004	88.3	84.6 C	69.0 B
3063	89.4	71.9 C	54.4 A
3065	85.4	85.4 C	79.2 A
3066	79.0	76.5 C	61.5 A
3068	90.6	84.4 C	75.0 B
3241	87.1	81.9 C	66.9 B
3242	79.8	66.3 B	54.8 A
3243	85.4	69.8 C	54.2 A
3244	96.9	93.8 C	87.5 B
3294	59.0	49.6 B	37.1 A
3295	86.3	83.1 C	54.4 A
3297	96.9	84.4 C	68.8 B
3298	88.8	70.6 C	57.5 A
3299	73.8	61.3 B	54.0 A
3309	76.3	73.8 C	71.3 B
Mean:	87.3	76.8	64.2
No. of clusters:	0	3	2

[1]Mean separation by cluster analysis (Scott and Knott 1974; Gates and Bilbro 1978): means followed by different letters belong to discretely different clusters.

geo-climatic variables. However at age 10 height was positively correlated with latitude (r = 0.43) and negatively correlated with length of growing season (r = -0.36). At age 16 height was no longer correlated with latitude but was negatively correlated with longitude (r = -0.31) and length of growing season (r = -0.36). Diameter at age 16 was correlated with latitude (r = 0.40), longitude (r = -0.30), elevation (r = -0.45) and length of growing season (r = -0.38). In general, the larger trees were from northern, low elevation provenances.

Damaging agents

During the first and second year after plantation establishment many seedlings were chewed or girdled by meadow voles. Few seedlings were actually killed as they put out new vigorous shoots from the root collar. Vole damage undoubtedly contributed to the large variance in growth evident during the early stages of this trial. At age 4 years, mean number of trees per plot with vole damage ranged from 0.1 to 1.4 (mean 0.8) (Table 6). In percentage, the damage ranged from 3 to 35% (mean 19%), however differences among provenances were not significant. Vole damage was not correlated with any of the geo-climatic variables of the provenances or with number of stems, survival, or any other of the growth or quality variables.

Damage by the leaf miner was evident on most seedlings at the time of measurement in 1971 (4 years). The percentage of leaves showing evidence of miner damage, by provenance, ranged from 40 to 73% (mean 60%) and differences among provenances were highly significant. The degree of damage could be divided into three discrete clusters.

Leaf miner damage was strongly correlated with geo-climatic variables of the provenances, *i.e.*, latitude (r = 0.64), elevation (r = -0.52), and length of growing season (r = -0.58). It was also weakly correlated with 4 year height (r = 0.35) and flowering at age 16 years. Seedlings from high elevation, southern provenances exhibited the least damage, *i.e.*, Kentucky (3294) and Georgia (2973).

Stem quality

A high proportion of the trees planted in this experiment developed multiple stems or large persistent branches. At age 4 years, mean number of trees with single leaders ranged from 0.9 to 2.3 (mean 1.6) (Table 6). In percentage, it ranged from 23 to 80% (mean 40%), however, the differences

Table 5. Provenance means for growth characters of yellow birch from 45 provenances at McDonald Corner, N.B.

Provenance	Height at ages 4 (cm)	10 (m)	16 (m)	Single stem height[1] (m)	DBH (cm)
2956	207.4	5.0 C[2]	7.6 B[2]	3.9	9.9 B[2]
2957	194.4	4.9 C	7.2 A	3.8	8.8 B
2958	180.8	2.2 A	6.5 A	3.4	7.9 A
2959	198.5	5.1 C	7.5 B	3.9	8.2 A
2960	201.2	5.0 C	7.9 B	4.1	9.9 B
2961	200.2	5.0 C	7.9 B	4.3	9.2 B
2962	225.5	5.3 C	7.8 B	4.1	9.9 B
2963	202.3	4.5 C	7.1 A	3.5	8.2 A
2964	198.9	4.6 C	6.9 A	3.5	7.7 A
2965	197.7	4.7 C	7.1 A	4.0	7.9 A
2966	216.2	4.9 C	7.4 B	3.7	8.9 B
2967	184.1	4.6 C	6.6 A	3.3	8.6 A
2968	230.0	5.0 C	7.3 A	4.3	8.5 A
2969	202.4	4.5 C	7.1 A	3.5	8.0 A
2971	197.9	5.0 C	7.6 B	4.0	9.2 B
2973	179.9	4.6 C	6.9 A	3.3	7.8 A
2976	202.0	4.9 C	7.7 B	3.9	9.5 B
2978	198.8	5.1 C	7.3 B	4.0	9.3 B
2979	184.2	4.1 C	7.8 B	4.4	9.1 B
2980	207.7	5.1 C	7.4 B	3.8	8.1 A
2982	206.2	4.3 C	7.5 B	4.2	8.4 A
2986	239.3	5.1 C	7.5 B	3.7	9.3 B
2996	210.3	5.0 C	7.4 B	4.0	9.2 B
2997	194.9	5.1 C	7.5 B	3.7	9.5 B
2998	203.6	5.0 C	7.4 B	3.6	9.0 B
2999	176.8	4.9 C	7.1 A	3.5	8.3 A
3000	204.3	5.1 C	7.6 B	3.6	8.7 B
3001	187.7	4.7 C	7.2 A	3.8	8.8 B
3002	203.8	5.1 C	7.4 B	3.7	9.4 B
3003	185.2	4.9 C	7.6 B	3.9	9.4 B
3004	180.9	4.7 C	7.3 B	4.0	8.1 A
3063	175.7	4.7 C	7.2 A	3.6	8.4 A
3065	189.6	5.2 C	7.8 B	3.6	9.6 B
3066	165.1	4.8 C	7.4 B	4.0	8.7 B
3068	190.2	5.0 C	7.5 B	3.8	9.2 B
3241	178.0	4.9 C	7.3 A	4.1	8.1 A
3242	192.8	5.1 C	7.6 B	4.0	9.0 B
3243	176.3	4.4 C	7.5 B	4.1	9.5 B
3244	213.6	5.3 C	7.4 B	4.0	8.9 B
3294	127.0	3.8 B	6.9 A	3.8	7.1 A
3295	205.4	5.0 C	7.2 A	3.6	8.5 A
3297	204.8	4.8 C	7.5 B	4.1	8.6 A
3298	196.7	4.7 C	7.1 A	3.5	8.1 A
3299	188.8	4.8 C	7.0 A	3.9	7.5 A
3309	185.8	4.8 C	7.3 A	3.7	8.9 B
Mean:	195.4	4.8	7.4	3.8	8.8
No. of clusters	0	3	2	0	2

[1]Height measured from ground to base of major branch.

[2]Mean separation by cluster analysis (Scott and Knott 1974; Gates and Bilbro 1978): means followed by different letters belong to discretely different clusters.

among provenances were not statistically significant. At age 10 years, the number of stems per tree ranged from 1.1 to 3.5 (mean 2.5) and the differences among provenances were highly significant resulting in two discrete clusters.

Number of stems was not correlated with any of the geo-climatic variables, but was correlated with 10 year height (r = 0.52) and 10 and 16 year survival (r = 0.40 and 0.41, respectively). Number of stems at age 10 was not correlated with total height, single stem height, or diameter at age 16 years. Thinning and pruning at age 13, to leave a single branch-free stem, resulted in considerable damage. Mean stem quality (butt damage) rating at age 16 ranged from 2.3 to 3.6 (mean 3.0) (Table 6). Differences among provenances were significant and separated into two groups. Butt damage was positively correlated only with number of stems at age 10 (r = 0.34).

Number of trees with dead tops (usually only the current years shoot) was recorded at age 10 years. The percentage of trees with dead tops ranged, by provenance, from 0.0 to 4.0% (mean 1.1%). There were no significant differences among provenances and there were no significant correlations with geo-climatic, growth, or damage variables. However, dead tops were correlated with flowering at age 10 years (r = 0.32), indicating a possible relationship with some unknown stress factor.

Differences among provenances in single stem height at age 16 years, which ranged from 3.3 to 4.4m (mean 3.8m), were not significant. As might be expected, single stem height was positively correlated with 16 year height (r = 0.64) and diameter (r = 0.32).

Flowering

Number of trees with female flowers (pistillate catkins) was recorded at ages 10 and 16 years. At age 10 years, the mean number of trees per plot bearing catkins ranged from 0.03 (1%) to 0.46 (12%) with mean 0.18 (5%) (Table 6) and at age 16 years the range was from 1.3 (33%) to 2.0 (50%) with mean 1.6 (40%). Differences among provenances in respect to flowering were highly significant at both ages, and were separated into two discrete groups.

At age 10 years, flowering was not correlated with geo-climatic, growth, quality, or damage variables except the presence of dead tops at age 10 years. At age 16 years flowering was weakly

Table 6. Provenance means for quality characters of yellow birch from 45 provenances planted at McDonald Corner, N.B.

Provenance	Damage by vole	Damage by insect	Single stems at age 4	No. of stems at age 10	Dead top	Butt rating	Trees with catkins age 10	Trees with catkins age 16
2956	0.4[1]	53.4 B[2]	1.4	2.5 A[2]	0.14	3.3 B[2]	0.14 A[2]	1.7 B[2]
2957	0.3	62.9 C	1.6	2.7 B	0.00	2.9 A	0.07 A	1.4 A
2958	0.5	60.1 C	1.1	1.1 A	0.00	2.3 A	0.19 A	1.3 A
2959	1.3	53.2 B	1.5	3.2 B	0.00	3.2 B	0.14 A	1.6 B
2960	0.6	55.2 B	1.5	2.4 A	0.00	2.6 A	0.08 A	1.4 A
2961	0.5	55.4 B	2.1	2.5 A	0.00	3.0 A	0.27 B	1.7 B
2962	0.6	61.4 C	1.5	3.1 B	0.00	2.8 A	0.25 B	1.6 B
2963	0.4	55.3 B	2.3	2.6 B	0.14	3.3 B	0.26 B	1.7 B
2964	0.9	63.3 C	1.1	2.7 B	0.00	3.6 B	0.08 A	1.7 B
2965	1.1	73.3 C	1.4	2.1 A	0.17	2.9 A	0.07 A	1.3 A
2966	0.1	67.3 C	1.8	2.3 A	0.03	2.8 A	0.18 A	1.7 B
2967	0.9	61.3 C	1.5	2.2 A	0.07	2.6 A	0.07 A	1.3 A
2968	0.9	63.8 C	1.1	2.7 B	0.04	2.9 A	0.22 B	1.7 B
2969	0.9	57.7 B	2.1	2.7 B	0.06	3.6 B	0.10 A	1.8 B
2971	1.4	55.0 B	1.4	2.4 A	0.04	2.8 A	0.28 B	1.7 B
2973	0.6	43.3 A	1.0	3.5 B	0.06	2.8 A	0.10 A	1.9 B
2976	0.9	52.8 B	1.8	2.6 B	0.09	3.0 A	0.17 A	2.0 B
2978	1.0	61.0 C	1.8	1.9 A	0.00	2.5 A	0.04 A	1.6 B
2979	0.9	58.0 B	2.3	1.8 A	0.00	3.1 B	0.06 A	1.4 A
2980	0.8	60.7 C	1.3	2.7 B	0.00	3.3 B	0.09 A	1.9 B
2982	0.9	68.2 C	1.8	2.3 A	0.04	3.3 B	0.07 A	1.3 A
2986	0.6	56.7 B	2.0	2.5 A	0.03	3.2 B	0.14 A	1.8 B
2996	0.1	61.0 C	1.8	2.4 A	0.10	2.9 A	0.22 B	1.7 B
2997	0.3	58.2 B	1.5	2.4 A	0.04	3.0 A	0.24 B	1.5 A
2998	0.5	69.1 C	1.3	2.8 B	0.06	3.1 B	0.46 B	1.5 A
2999	0.6	63.0 C	1.5	2.9 B	0.03	2.8 A	0.13 A	1.5 A
3000	0.9	62.8 C	2.0	2.8 B	0.00	2.8 A	0.11 A	1.3 A
3001	1.0	68.6 C	1.6	3.0 B	0.06	2.4 A	0.31 B	1.7 B
3002	1.4	51.5 B	1.9	2.7 B	0.04	3.2 A	0.04 A	1.7 B
3003	0.4	61.2 C	1.6	2.5 A	0.00	2.8 A	0.16 A	1.4 A
3004	0.3	63.4 C	1.9	2.6 B	0.06	2.9 A	0.17 A	1.5 A
3063	1.4	63.2 C	1.9	2.5 A	0.00	2.9 A	0.07 A	1.8 B
3065	0.6	61.9 C	1.3	2.4 A	0.00	2.7 A	0.13 A	2.0 B
3066	0.9	56.5 B	1.8	2.3 A	0.00	2.7 A	0.17 A	1.3 A
3068	1.0	61.5 C	1.9	2.8 B	0.07	3.3 B	0.10 A	1.5 A
3241	1.4	58.4 B	1.3	2.8 B	0.09	2.8 A	0.21 B	1.6 B
3242	0.6	61.0 C	1.4	2.9 B	0.00	2.9 A	0.03 A	1.7 B
3243	1.3	64.5 C	2.0	2.3 A	0.00	2.9 A	0.37 B	1.6 B
3244	0.4	66.1 C	1.9	2.6 B	0.03	2.9 A	0.42 B	1.4 A
3294	1.0	40.4 A	1.4	2.3 A	0.06	3.4 B	0.09 A	1.9 B
3295	0.5	69.1 C	2.4	1.8 A	0.16	2.4 A	0.43 B	1.6 B
3297	0.8	60.3 C	1.3	2.5 A	0.09	3.1 B	0.32 B	1.8 B
3298	0.8	66.3 C	2.1	2.3 A	0.08	3.0 A	0.32 B	1.6 B
3299	0.9	51.4 B	0.9	3.5 B	0.14	3.2 B	0.37 B	1.9 B
3309	0.9	54.1 B	1.8	2.3 A	0.03	2.9 A	0.24 B	1.7 B
Mean:	0.8	59.8	1.6	2.5	0.05	3.0	0.18	1.6
No. of clusters:	0	3	0	2	0	2	2	2

[1]Units are numbers per 4-tree plot except insect (leaf miner) damage, %, and butt rating. Butt rating: 1 = perfect without previous multiple stem, 2 = no damage, 3 = moderate, 4 = serious damage, and 5 = severe damage (dying).

[2]See footnote in table 5.

correlated with latitude (r=0.37) and length of growing season (r=0.35) as well as with the number of stems at age 10 and leaf miner damage at age 4 years.

DISCUSSION

Yellow birch is a genetically variable species. Significant differences among provenances have been demonstrated for survival, winter injury, growth, chilling requirements, growth initiation, and growth cessation (Clausen 1973a). Most of these variables are weakly correlated with geo-climatic variables of the provenances such as latitude and length of growing season. However, variation among provenances from the same or at least similar geo-climatic regions is large. A similar pattern of genetic variation emerges from the field studies. Genetic variation among provenances is large, however, correlations with geo-climatic variables, although significant, are generally too weak to provide a basis to identify areas of better provenance for use in a specific area. In general the pattern of variation has a small clinal component which is often masked by the much larger non-clinal ecotypic or random component.

Yellow birch from south of about 45° N latitude as well as from the extreme limits of the species range, does not grow well in central New Brunswick. Trees of these provenances exhibit below average survival, inferior growth, or both at age 16 years. Trees from 10 of the 20 provenances from 44.9° N or above, excluding 5 from the extreme limit of the species range, were average, or above, for survival, height and diameter at age 16, and consistently fell in the highest discrete cluster for each of the attributes. These 10 better provenances were well distributed across the range of longitudes sampled, *i.e.*, Minnesota (2966), Wisconsin (2962), Michigan (2960, 2961), Ontario (3003), Quebec (2997, 2998), New Brunswick (3068), Nova Scotia (3065), and Newfoundland (3244). There does not appear to be any one area of better provenance for use in central New Brunswick.

The absence of a distinct pattern for survival and growth, especially in the northern part of the species range, *i.e.*, 44 to 48° N is unexpected. It suggests that selection in response to geo-climatic variables is not as important as it is for many other northern temperate species. This lack of a distinct pattern is similar to that of red spruce (Fowler *et al.* in press), which, like yellow birch, is a late successional species. Neither of these species are especially well adapted for establishment and growth in early successional environments, *e.g.*, plantations. Yellow birch is a component of a large number of forest associations and may be present at most stages of forest succession, however, it most commonly occurs in climax associations (Fowells 1965). Under forest conditions the species usually develops a single stem. In more open situations, including plantations, yellow birch has a propensity to develop multiple stems. This was well demonstrated in this experiment.

The significant age to age correlation for survival, height and diameter at ages 10 and 16 years suggests that it is possible to identify superior provenances at about age 10 years. This could be of some advantage in identifying superior seed sources, e.g., seed production stands.

Differences among provenances in respect to number of stems, thinning and pruning damage, leaf miner damage, and flowering, although statistically significant and of some biological interest, are of little practical importance.

Clausen (1973b) reported on a study of within provenance variation (among open-pollinated families) of many of the same provenances included in this study. He reported that within provenance variation for height of 2, 3, and 4-year-old seedlings was often greater than differences among the 21 widely separated provenances tested. Although height growth of yellow birch is under strong genetic control, selection based on phenotypic evaluation in the wild is not effective, *i.e.*, parent-progeny correlation is weak (Clausen 1973b).

Implication for tree improvement

Yellow birch is not, and perhaps never will be, an important reforestation species. Current annual seedling production in the Maritimes seldom exceeds 10 thousand trees, which is hardly enough to justify any expenditure in tree improvement. Methods to regenerate and tend yellow birch *in situ* are well established (Fowells 1965). Harvesting techniques that favor advanced regeneration, or that expose mineral soil in the presence of a suitable seed source, are effective. Cleaning and spacing young stands to favor yellow birch can be used effectively to favor high quality trees. Using current technology it is doubtful if planting yellow birch is a viable alternative to regenerating and tending the species *in situ*. Before yellow birch can be seriously

considered for reforestation it will be necessary to develop cost-effective techniques for its establishment and early culture in plantations.

The possibility of producing a genetically superior yellow birch is good. The species is genetically variable at both the provenance and within provenance levels of variation. It follows that it should be possible to produce yellow birch that have considerably better growth characteristics than those that are currently available. Yellow birch is a prolific seed producer, with crops of over 60 million seeds/ha reported in good flowering years (Gross and Harnden 1968). The interval between good seed crops is about two years (Gilbert 1960). This suggests that the number of seed trees required to service a reforestation program is small. In the following we suggest a relatively low-cost procedure to produce genetically improved yellow birch for reforestation in the Maritimes.

In a good flowering year, collect seeds from 20 yellow birch in each or 5 or more locations within the Region. These trees should be healthy, at least 100m apart, and located in an area where they will not be cut. The trees need not be "plus" trees and should be located where seed collection will be convenient, *i.e.*, along roads where they can be reached with cone collection equipment. The location of each tree should be identified for future seed collection and appropriately marked.

The seeds, kept separate by mother tree, should be used to establish provenance-progeny tests on at least three appropriate sites in areas where yellow birch is considered to be potentially important for reforestation. Early results from these tests will identify genetically poor trees which can immediately be eliminated from the program. By age 10 it should be possible to identify best provenances and best individuals within provenances, at least in respect to survival and growth characteristics. Seed collection can then be directed to these trees. Subsequent evaluation of the materials in the test at 15-20 years will make it possible to identify the genetically best trees in respect to both quality and growth.

If yellow birch ever does become an important reforestation species in the Maritimes a more sophisticated and more expensive improvement strategy may be appropriate.

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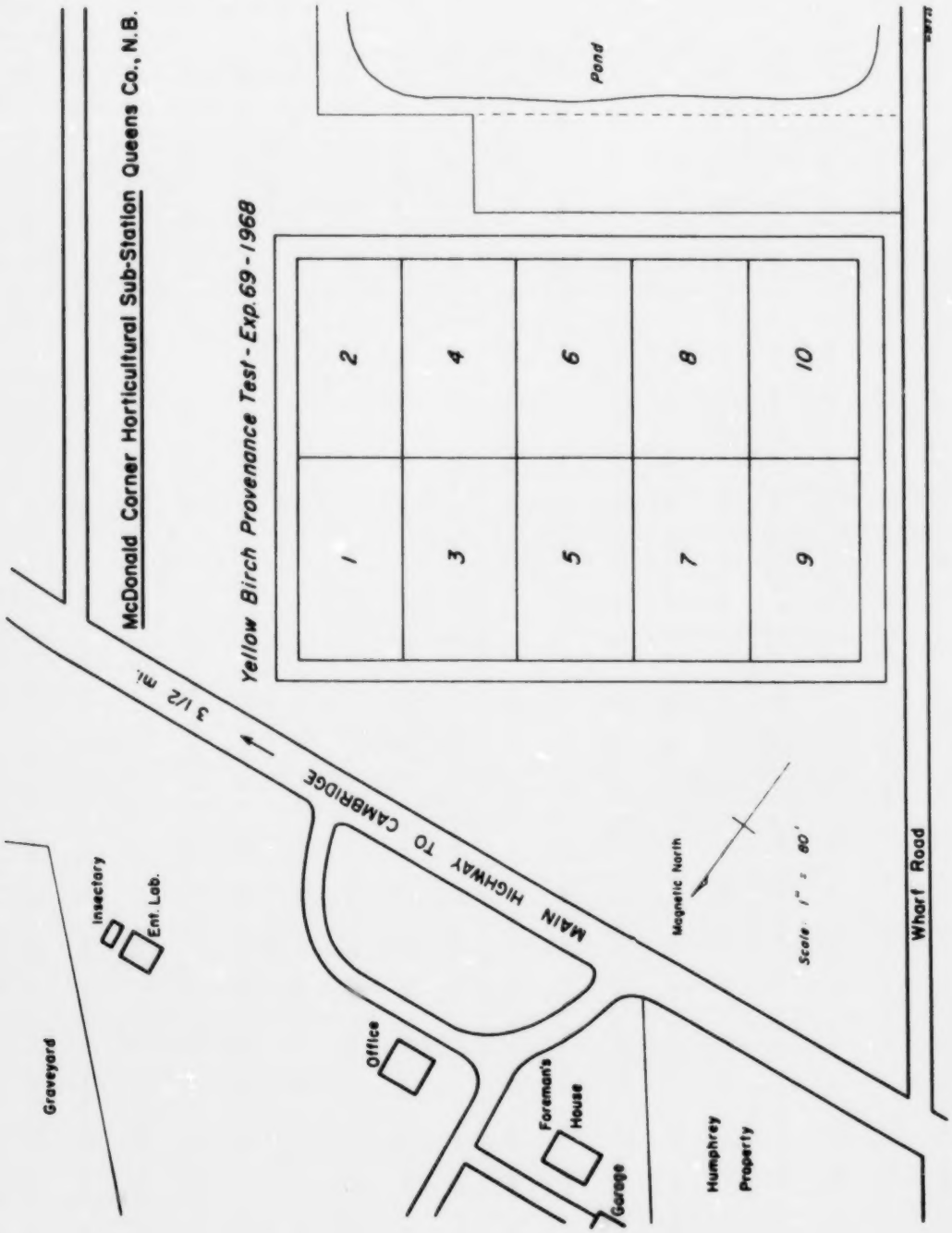
Appendix I. Location and general layout of a trial of yellow birch from 45 provenances planted at McDonald Corner, N.B. in 1968.



Appendix II. Detailed layout of a trial of yellow birch from 45 provenances planted at McDonald Corner, N.B. in 1968 (. = plot trees, o = filler trees, + = surround trees).